Self-assessment

ECTION A
ualitative assessment

State Newton's **first** law of motion. This law expresses the concept of **inertia**. Explain what is meant by the term inertia.

In which of the following cases does a **resultant force** act on the body:

(a) a bicycle travelling along a straight, level road at constant velocity

(b) an electron orbiting a nucleus at constant velocity

(c) a bumble bee hovering in still air

(d) a car accelerating uniformly?

Define the **momentum** of a body and state its SI unit.

State Newton's **second law of motion in terms of momentum**.

Use the equation $\boxed{F = ma}$ to define the SI unit of force.

State Newton's **third** law of motion. Explain how it applies in the following situations:

(a) a body falling freely towards Earth

(b) an electron orbiting a nucleus

(c) a sprinter starting to accelerate from rest

(d) a rocket motor firing in outer space to accelerate a spacecraft.

A fireman of mass (M) slides down a vertical pole with an average acceleration (a). If the acceleration due to gravity is (g), derive an expression for the average frictional force (F) exerted on him, in terms of M, g and a.

State the **principle of conservation of linear momentum**, and state under what conditions it is valid.

Explain what is meant by the **impulse** of an applied force.

(a) State the unit of **impulse** and show that this unit is the same as that of linear momentum.

(b) Explain the significance of the **area** enclosed by a **force/time** graph and the time axis.

SECTION B
Quantitative assessment

(***Answers:*** 0.020; –0.026; 0.95; –1.1; –1.5; 2.7; 5.0; 8.8; 9.6; 10; 15; 17; 18; 28; 40; 40; 50; 96; 130; 130; 1.0×10^3; 1.2×10^3; -1.3×10^5.)

1. An ice hockey puck of mass 0.75 kg is struck and moves off with an initial horizontal velocity of 24 m s^{-1} across the surface of a frozen lake. If it travels 190 m before coming to rest, calculate
   (a) the average retardation of the puck
   (b) the average friction force on the puck.

2. A submarine of mass 5.0×10^6 kg is moving with a velocity of 8.5 m s^{-1} while fully submerged. The power is suddenly shut off, and the submarine takes 5.5 minutes to come to rest. Calculate the average retardation and retarding force on the submarine.

3. An eccentric fisherman insists on weighing his fish inside the lift of a tall building. If he hooks a 4 kg sea bass onto his weighing machine, calculate the indicated weight when the lift is
   (a) stationary
   (b) accelerating upwards at 2.5 m s^{-2}
   (c) accelerating downwards at 3.0 m s^{-2}
   (d) moving upwards at a constant velocity of 4.0 m s^{-1}.

4. A hot air balloon with its basket and passengers has a total mass of 1150 kg, including the air in the balloon envelope. If, when it is stationary in still air, 100 kg of ballast is thrown out, calculate:
   (a) the resultant force on the balloon
   (b) its initial acceleration.

5. Fine salt is deposited from negligible height at a rate of 12 kg s^{-1} onto a conveyor belt moving at 8.0 m s^{-1}. Calculate the force needed to keep the belt moving at this velocity.

6. A jet of water issues horizontally from a nozzle of cross-sectional area 5.0×10^{-3} m^2 at a rate of 25 kg s^{-1}. Calculate:
   (a) the velocity of the water jet
   (b) the rate of change of momentum of the water
   (c) the force exerted by the water on the nozzle.

Self-assessment *continued*

7. The wind in a severe storm is blowing at a velocity of 30 m s^{-1} perpendicularly to the wall of a large barn, of area 80 m^2. Assuming that the air moves parallel to the wall of the barn after striking it, calculate the pressure exerted on it, assuming the air density to be 1.3 kg m^{-3}.

8. A helicopter together with its passengers has a total mass of 8500 kg and its rotor blade diameter is 30 m. Calculate the velocity of the air forced downwards by the rotating blades when the helicopter is hovering over an oil platform prior to landing. (Assume the air density to be 1.3 kg m^{-3}.)

9. A bumble bee hovers in mid-air by pushing the air downwards with its wings. If the total area swept out by the beating wings is 1.5 cm^2, and the mass of the bee is 2.0 g, calculate the downward velocity of the air.

10. A large bowling ball of mass 6.0 kg moving with velocity 3.0 m s^{-1} has a head-on collision with a single pin, of mass 0.50 kg. If the pin moves off with a velocity of 4.0 m s^{-1}, calculate the velocity of the bowling ball after the collision;

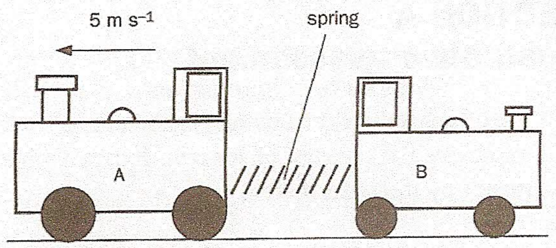
11. A fully-laden Range Rover of total mass 1800 kg travelling at 20 m s^{-1} collides with a Reliant Robin of mass 850 kg. Assuming the two vehicles separate after impact, calculate the velocity of the Range Rover after impact if:

(a) the Reliant is initially stationary, and its velocity after impact is 10 m s^{-1}

(b) the Reliant's initial velocity is 12 m s^{-1} in the same direction as the Rover, and its velocity after collision is 18 m s^{-1}.

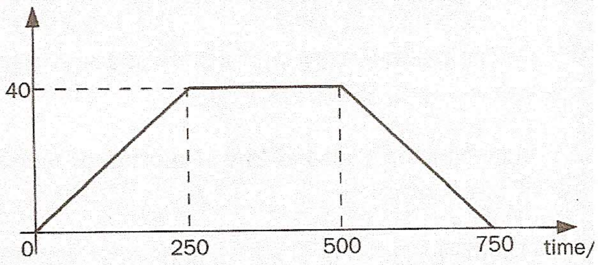
(c) If the two cars become stuck together in the impact, calculate their combined velocity after the collision if the Reliant's initial velocity is 15 m s^{-1} in the same direction as the Range Rover.

12.



Two toy trains A and B of masses 0.70 kg and 0.40 kg respectively are held together on a level frictionless track against the force exerted by a compressed spring. When the trains are released, A moves to the left with an initial velocity of 5 m s^{-1}. Calculate the initial velocity of B.

13.



A force F acts on a body which is initially stationary. The graph shows how F varies with time t.

(a) Sketch a velocity/time graph for the 750 μs period and **explain** its shape.

(b) Explain what the area enclosed by the F/t graph represents.

(c) Calculate the momentum gained by the body.

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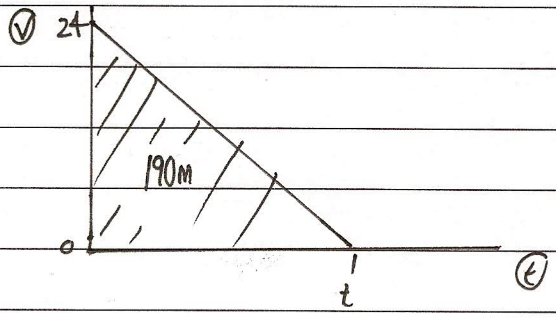
(Q1)

$M = 0.75\ kg$

$V_h = 24\ ms^{-1}$

$S = 190\ M$

+ →



$AREA = 190 = \frac{1}{2} \times 24 \times t$

$t = 15.8\ s$

a) RETARDATION = ACC $= \frac{V-u}{t} = \frac{0-24}{15.8} = -1.52\ ms^{-2}$

b) FORCE: $F\Delta t = \Delta(mv)$

$F = \frac{0.75 \times 24}{15.8} = -1.14\ N$ REMEMBER FORCE IS A VECTOR

(Q2)

$M = 5.0 \times 10^6\ kg$

$V = 8.5\ ms^{-1}$

$t = 5.5$ MIN to stop $= 330\ s$

$p = mv = 5 \times 10^6 \times 8.5$

$= 4.25 \times 10^7\ kgms^{-1}$

$F = \frac{\Delta mv}{t} = \frac{4.25 \times 10^7}{330} = -1.288 \times 10^5\ N$

(Q3)

$M = 4\ kg$

a) $W = 4 \times 10 = 40N$

b) $2.5\ ms^{-2}\uparrow$ MAKES g EFFECTIVELY $10 + 2.5 = 12.5$ $4 \times 12.5 = 50N$

c) $3\ ms^{-2}\downarrow$ MAKES g EFFECTIVELY $10 - 3 = 7$ $4 \times 7 = 28N$

d) $g = 10$ $10 \times 4 =$ $40N$

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(Q4) $M_i = 1150\,kg$

$M_f = 1050\,kg$

$F_{UPWARDS}$ = WEIGHT OF DROPPED BALLAST (FORCES WERE BALANCED BEFORE SO UPTHRUST = TOTAL WEIGHT BEFORE DROP)

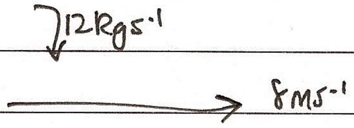
$= 100 \times 10 = \underline{1000\,N}$

$F = ma$

$1000 = 1050 \times a$ $\quad a = \underline{\underline{0.952\,ms^{-2}}}$

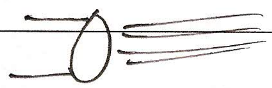
(Q5) FLOW $12\,kg\,s^{-1}$

MOTION $V = 8\,ms^{-1}$



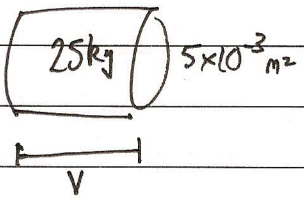
$F = \frac{\Delta mv}{t}$ $\quad$ PER SECOND $t = 1$ $\quad F = 12 \times 8 = \underline{\underline{96\,N}}$

(Q6)



$A = 5 \times 10^{-3}\,m^2$

Vol $= 25\,kg\,s^{-1}$



$\rho = 1000\,kg\,m^{-3}$

$25\,kg = 0.025\,m^3$

$V \times 5 \times 10^{-3} = 0.025$

$V = \underline{\underline{5\,ms^{-1}}}$

$\Delta mv = 25 \times 5 = \underline{125\,kg\,ms^{-1}}$

$F = \frac{\Delta mv}{t} = \frac{125}{1} = \underline{\underline{125\,N}}$

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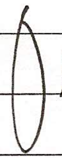
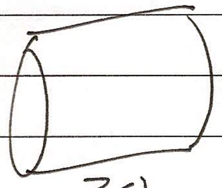
(Q7) $V = 30ms^{-1}$





VOLUME = $2400 m^3$ PER SECOND
MASS = 3120 kg

$\rho_{AIR} = 1.3 kgm^3$

$\Delta MV = 3120 \times 30 = 93600 kgms^{-1}$ PER SECOND

$F = \frac{\Delta MV}{t} = \underline{\underline{9.36 \times 10^4 N}}$

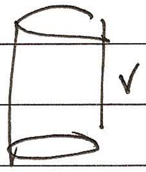
$P = \frac{F}{A} \quad \frac{9.36 \times 10^4}{80} = \underline{1170 Nm^{-2}}$

(Q8) $M = 8500 kg$

ROTOR $d = 30m \Rightarrow$ AREA $= \pi r^2 = \underline{\underline{706.8 m^2}}$

TO REMAIN STATIONARY $F = 8500 \times 10$ (BALANCE WEIGHT)

$= \underline{\underline{8.5 \times 10^4 N}}$



MASS OF AIR } ?
VELOCITY of AIR }

(t = 1 SECOND)

VOLUME IN ONE SECOND $= V \times 706.8$

MASS = DENSITY × VOLUME $= \rho \times V \times 706.8$

$\Delta MV = \rho = \rho \times V \times 706.8 \times V$

$= 918.84 \times V^2$

$F = \Delta MV$ $(t=1)$

$8.5 \times 10^4 = 918.84 \times V^2$

$\sqrt{\frac{8.5 \times 10^4}{918.84}} = V = \underline{\underline{9.62 ms^{-1}}}$

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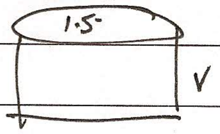
(Q9) $A = 1.5cm^2 = 0.0015m^2$

$M = 2g = 0.002 kg$

$V = ?$



$(1.5cm^2 = 0.00015m^2)$

FOR 1 SECOND

VOLUME = $V \times 0.0015$

$\rho \times$ VOLUME = MASS = $1.3 \times V \times 0.0015$

MASS × VELOCITY = $1.3 \times 0.0015 \times V^2$ = mom

Δ MOM = F = $0.002 \times 10 = 0.02 = 1.3 \times 0.0015 \times V^2$

$$V = \sqrt{\frac{0.02}{1.3 \times 0.0015}} = 10.1 ms^{-1}$$

(Q10)

B4 | AFTR

$M_B = 6 kg$ | $M_P = 0.50 kg$ | $M_B = 6 kg$

$V_B = 3ms^{-1}$ | $V_P = 4ms^{-1}$ | $V_B = ?$

MOM B4 $= 6 \times 3 = 18 kgms^{-1}$

MOM AFTR $= 0.5 \times 4 = 2 kgms^{-1}$

SO $16 kgms^{-1}$ LEFT FOR BALL

$p = mv$

$16 = 6 \times V$

$\frac{16}{6} = 2.67ms^{-1}$

(Q11) $M_B = 1800 kg$ $V = 20ms^{-1}$ $M_R = 850 kg$

a) TOTAL MOM = $1800 \times 20 = 3.6 \times 10^4 kgms^{-1}$

AFTER : ROBIN RELIANT = $850 \times 10 = 8500 kgms^{-1}$

$3.6 \times 10^4 - 8.5 \times 10^3 = 27500 kgms^{-1}$ (LEFT FOR RANGE)

$\frac{27500}{1800} = 15.2ms^{-1}$

b) MOM BEFORE = $3.6 \times 10^4 + 850 \times 12 = 4.62 \times 10^4 kgms^{-1}$

MOM AFTER : ROBIN = $850 \times 18 = 15300 kgms^{-1}$

$4.62 \times 10^4 - 1.53 \times ^4 = 3.09 \times 10^4 kgms^{-1}$ ('LEFT' FOR RANGE)

$\frac{3.09 \times 10^4}{1800} = 17.1ms^{-1}$

(E)

MOM p47

Q11 CONTINUED...

MOM BEFORE $= (1800 \times 20) + (850 \times 15)$

$= 4.875 \times 10^4 \ kgms^{-1}$

MOM AFTER $= MV$

$= (1800 + 850) \times V$

$\frac{4.875 \times 10^4}{(1800+850)} = V = \underline{18.396 ms^{-1}}$

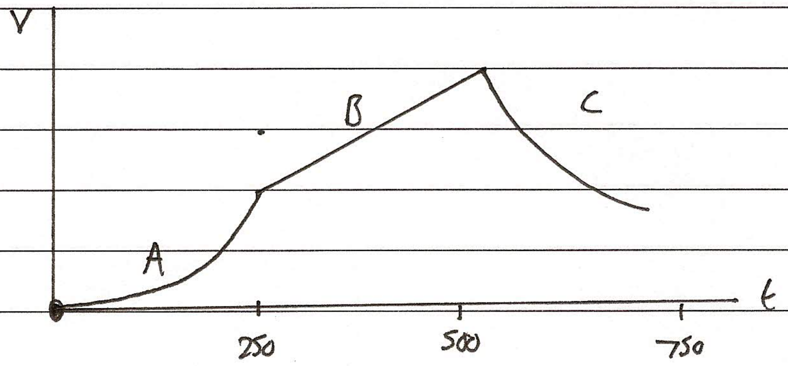
Q12 $M_A = 0.7kg$ $M_{B4} = 0$ ← +

$M_B = 0.4kg$ $M_{AFTER} = 0$

$(0.7 \times 5) + (0.4 \times V_B) = 0$

$V_B = \frac{0.7 \times 5}{0.4} = \underline{\underline{8.75 ms^{-1}}}$

Q13



1a) A (0-250μs) INCREASING FORCE → INCREASING ACCELERATION → INCREASING GRADIENT
B (250-500μs) CONSTANT FORCE → CONSTANT ACCELERATION → STRAIGHT LINE
C (500-750μs) DECREASING FORCE → DECREASING ACCELERATION → DECREASING GRADIENT

1b) AREA UNDER F/t GRAPH = IMPULSE = CHANGE IN MOMENTUM

1c) AREA $= \left(\frac{1}{2} \times 40 \times 250 \times 10^{-6}\right) \times 2 + (40 \times 250 \times 10^{-6}) = \underline{\underline{0.02 \ kgms^{-1}}}$

(DON'T FORGET $\times 10^{-6} s$)